Real world emissions and in-use compliance

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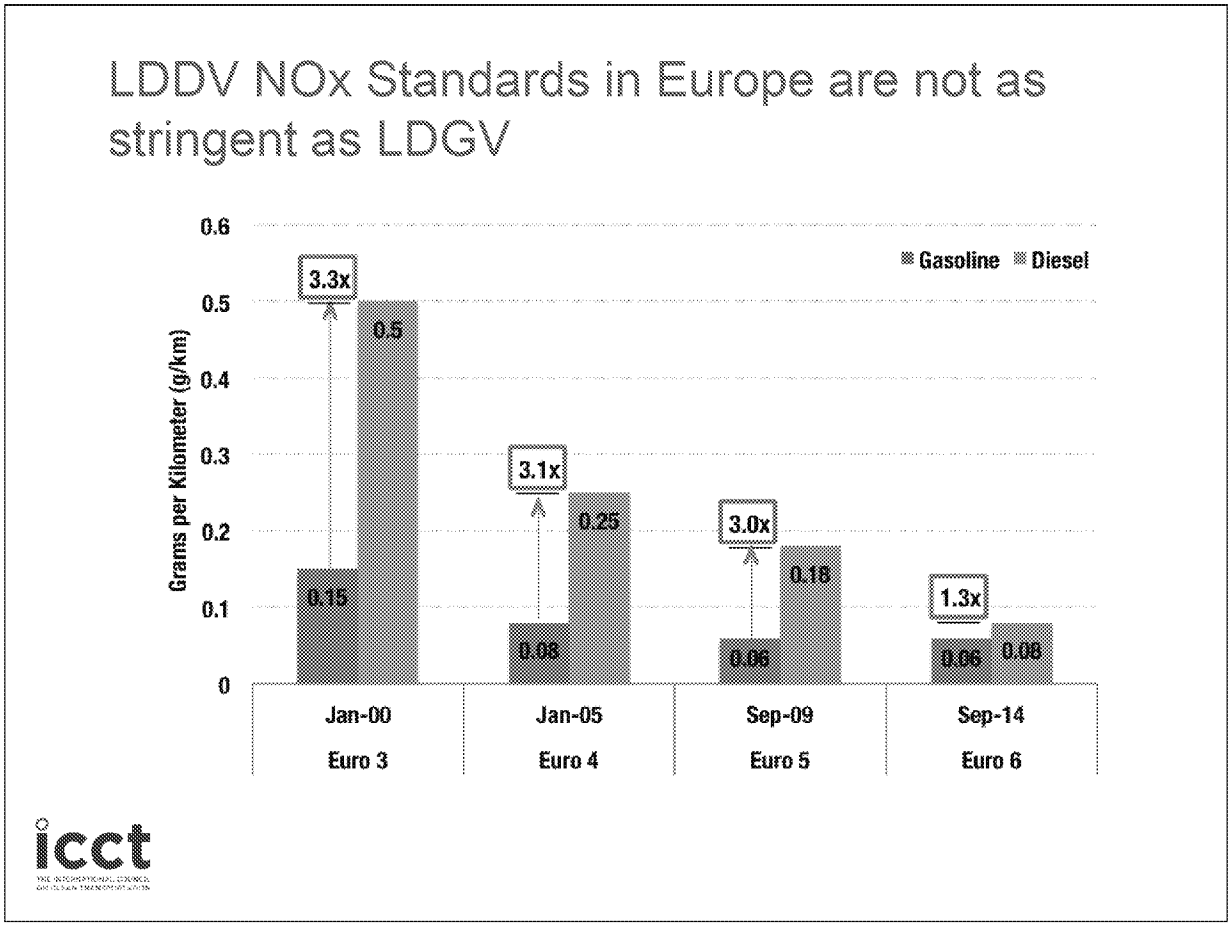
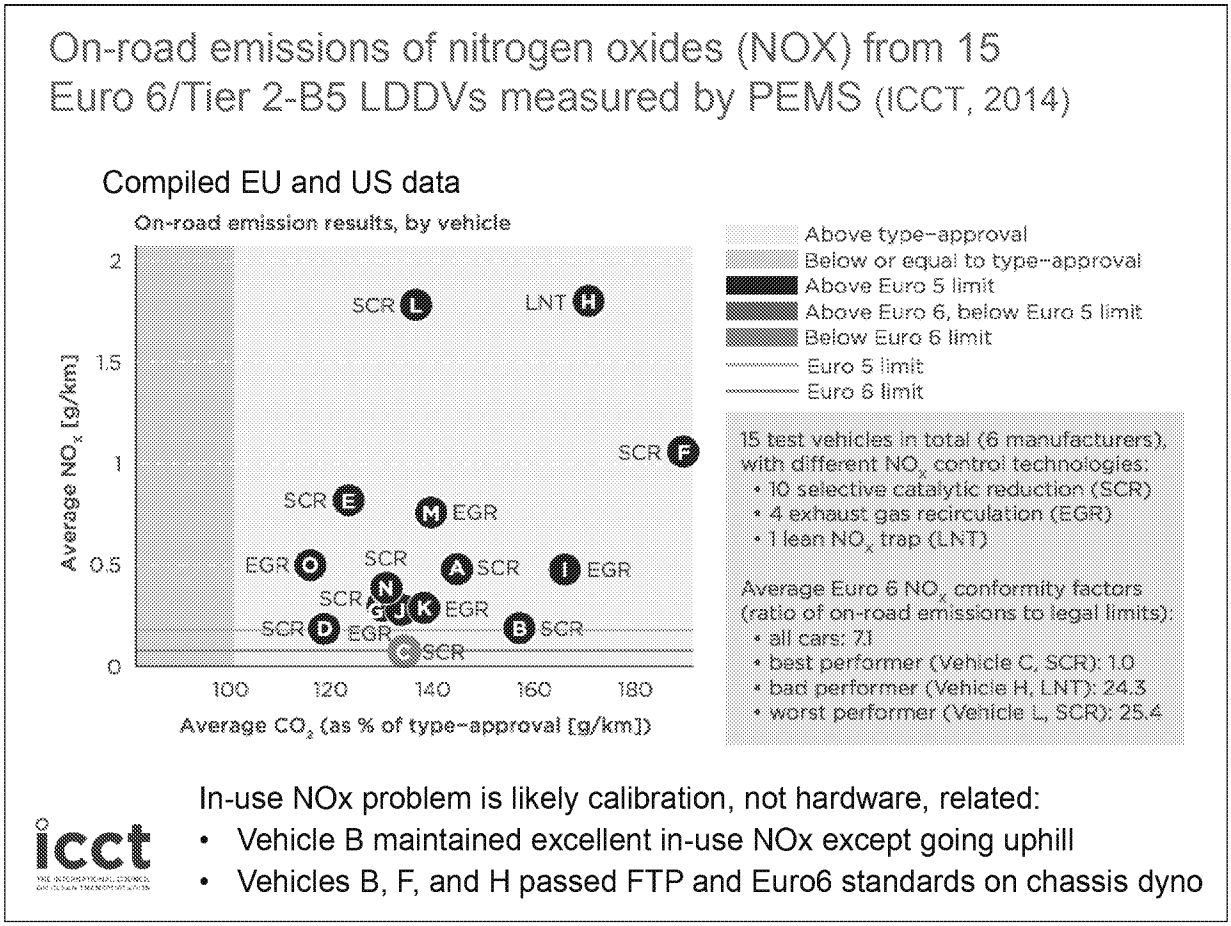
Screenshot from ICCT webpage



Standards are less stringent for diesels than for gasoline. This creates a challenge for air pollution experts and continued to image of the dirty diesel. But the gap has diminished from 3X to only 30%.

Standards regulating NOx and other exhaust emissions from passenger cars in the EU have become more stringent over time: The permissible limit for emissions of nitrogen oxides (NOx) from diesel cars declined from 500 milligrams per kilometer (mg/km) under Euro 3 (effective January 2000) to 80 mg/km under Euro 6 (effective September 2014). New passenger vehicles are certified as meeting the standards on the basis of test results obtained under laboratory conditions. But studies have suggested that on-road performance does not dependably reflect these "type-approval" results.

Diesel vehicles in the EU are allowed a much higher NOx emission level than gasoline cars. In 2000, when the Euro 3 standard was introduced, the allowed level was 0.5 g/km, more than three times as much as for gasoline vehicles. Yet, as vehicle tests show, even back then the real on-road emission levels were closer to 1.0 g/km, i.e., much more than actually allowed by the standard. Still, the vehicles received their type-approval and could be sold, as the Euro emission standards have to be met under laboratory conditions only. Over time, emission limits got stricter, and the current Euro 5 emission standard sets a limit of 0.18 g/km for NOx diesel emissions. This is still more than three times as high as for gasoline vehicles, but of course much lower than back in 2000. However, recent research suggests that the on-road emissions did not really change at all during the last decade. The values measured are in the range of 0.8 g/km, only 20% lower than in 2000 and more than four times higher than allowed by the Euro 5 emission limit.



This study, a meta-analysis of PEMS data from EU (Euro 6) and US (Tier 2 Bin 5/ULEV II) diesel passenger cars, documents the wide discrepancy that exists between official certification or type-approval emissions of nitrogen oxides (NOx) from new diesel passenger cars and actual NOX emissions from those vehicles during real-world, everyday operation.

This study analyzed the on-road emissions performance of fifteen new diesel passenger cars, twelve certified to the Euro 6 standard and three to the US equivalent (Tier 2 Bin 5), using portable emissions measurement systems (PEMS), which provide a continuous stream of vehicle data signals including emission rates, velocity, acceleration, road gradient and exhaust temperature.

Emissions were measured over 97 trips, totaling more than 140 hours of operation and 6,400 kilometers driven. The high temporal and spatial resolution of PEMS datasets permitted the analysis to link elevated NOx mass emission rates to the driving conditions that caused them.

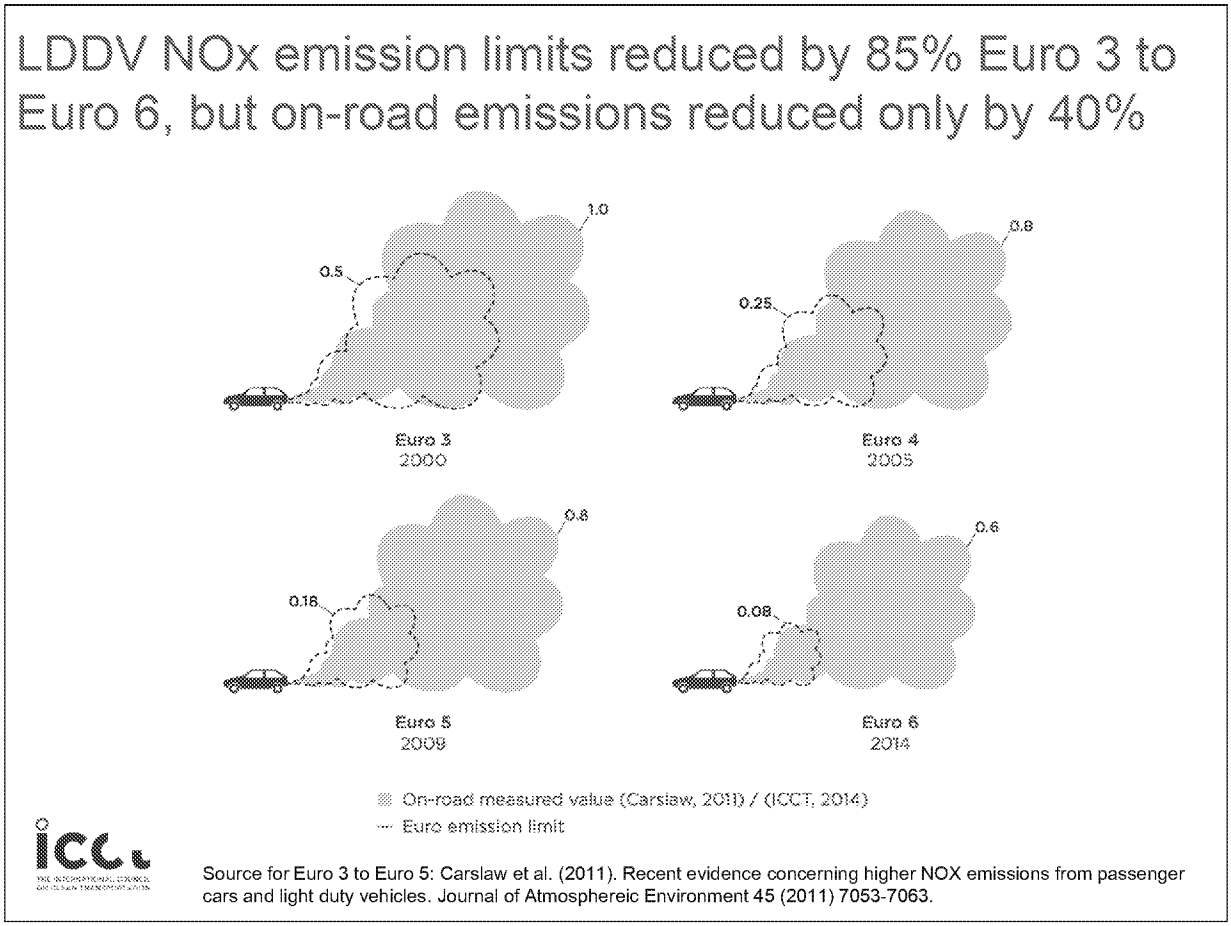
This is the first systematic analysis of the real-world performance of modern diesel passenger cars, and the most comprehensive profile available of the on-road behavior of the latest generation of diesel passenger cars.

On average, real-world NOX emissions from the tested vehicles were about seven times higher than the limits set by the Euro 6 standard. If applied to the entire new vehicle fleet, this would correspond to an on-road level of about 560 mg/km of NOX (compared to the regulatory limit under Euro 6 of 80 mg/km). This is compelling evidence of a real-world NOX compliance issue for recent technology diesel passenger cars, for both the EU and US test vehicles.

The data also strongly suggest that the problem is primarily calibration related and that SCR systems are capable of maintaining low NOx under the large majority of in-use driving conditions:
Vehicle B was a BMW X5, perhaps the largest, heaviest vehicle tested. Despite this, it maintained low NOx emissions under all in-use driving conditions, except for extended uphill driving. Even though it had a higher proportion of uphill driving that any other vehicle tested, which artificially inflated its average NOx emissions, it still had the 2nd lower average NOx emissions. If this vehicle can maintain low in-use NOx emissions, there is no reason why other vehicles cannot do the same.
Vehicles B, F, and H were all tested at CARB and all passed both the FTP and Euro6 standards on the chassis dyno. This strongly

supports that the hardware was operating as designed, but the vehicles were not properly calibrated at higher loads and faster transients.

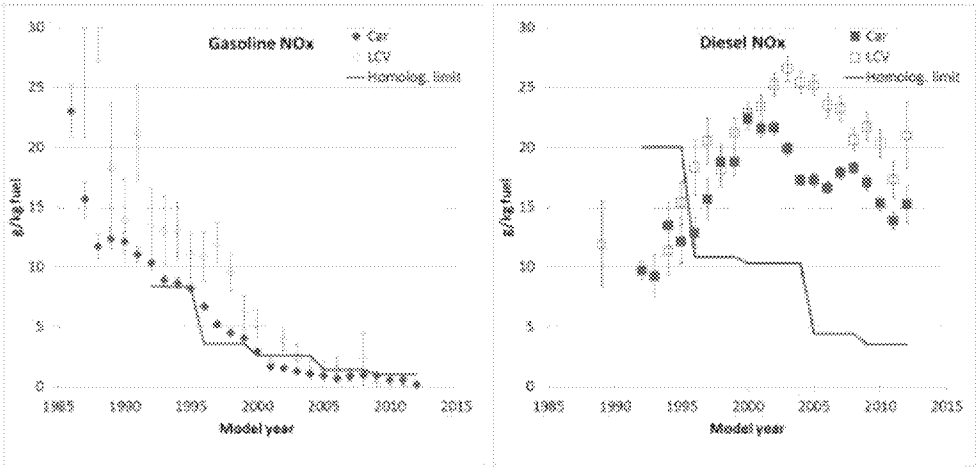
Note that the vehicles labeled "EGR" had only in-cylinder NOx controls. Thus, it is not surprising that higher loads in-use would increase NOx emissions, as engine-out NOx is directly proportional to combustion temperatures.



I don't know if you want to include this. It's based upon comparing the Euro6 data from ICCT's PEMS report to earlier data from Carslaw (2011).

It makes a simple point – that NOx reductions on the test cycle have been a lot larger than reductions in the real world.

On-road emission behavior as depicted by 13 years of Remote Sensing data



Chen & Borken-Kleefeld, Real-driving emissions from cars and light commercial vehicles - Results from 13 years remote sensing at Zurich/CH Atmospheric Environment, 88:157-164 (May 2014)

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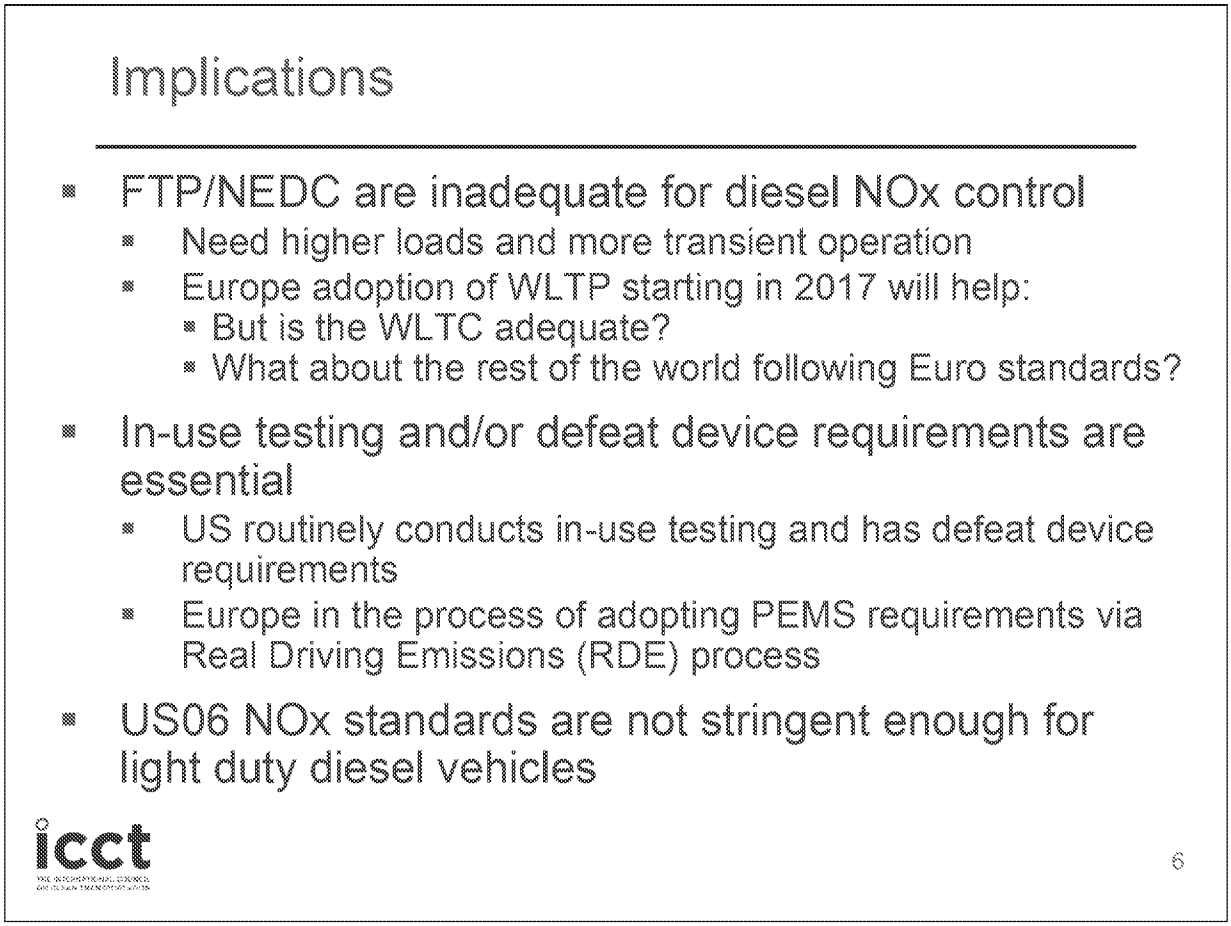
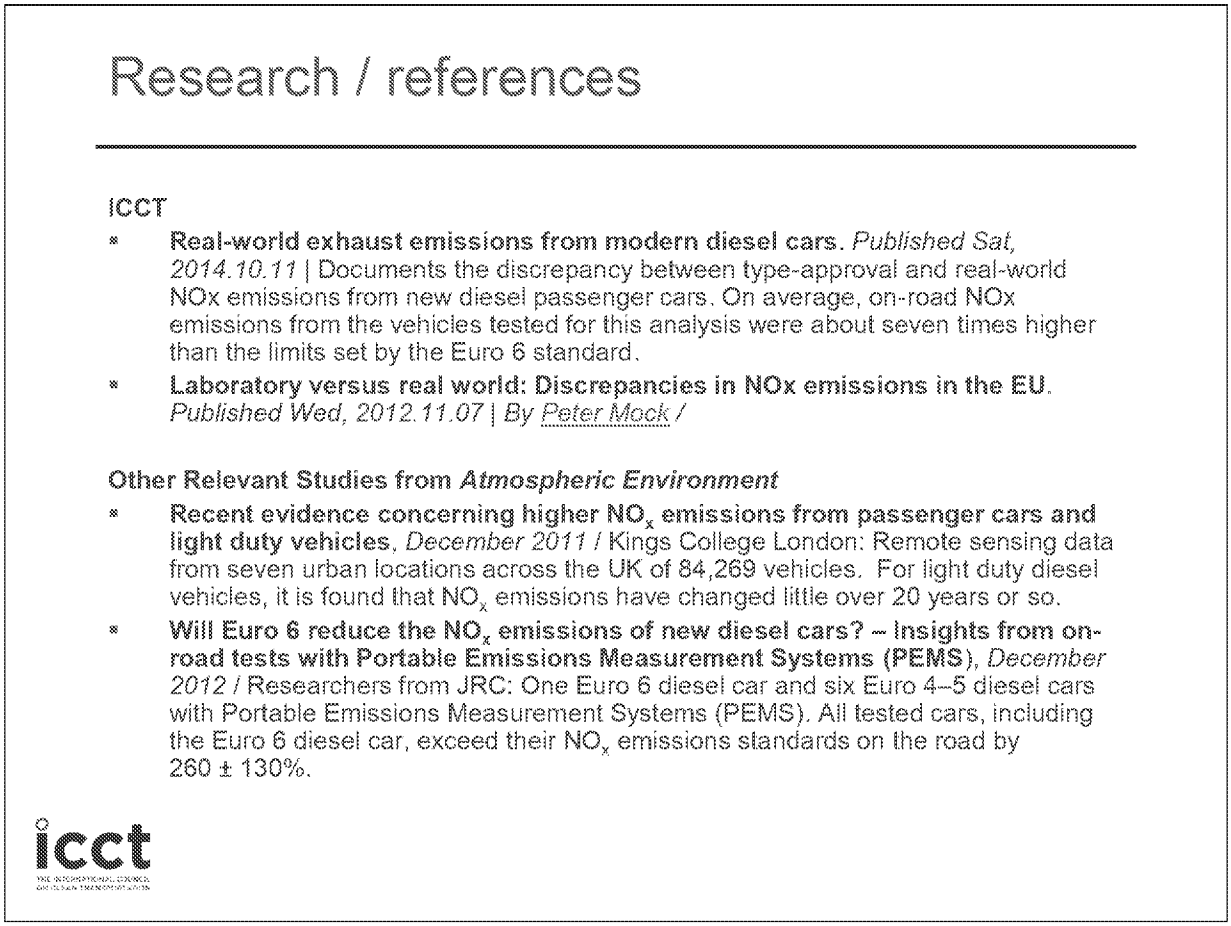
We report on long-term remote sensing measurements of light duty vehicle emissions at one site close to Zurich/Switzerland. The time series of annual measurements at the same site between 2000 and 2012, the same season, and virtually the same instrument is unique, probably worldwide. We analyze the development of unit exhaust emissions from model years 1985 until 2012, covering all five Euro emission limit stages in force. NOx emissions from both diesel cars and light commercial vehicles have actually increased in real-driving over time although emission limits have been progressively tightened. This behavior is explained mostly by a significant discrepancy between engine conditions during real-driving and the homologation test procedure. This discrepancy is not important for the other pollutants or for gasoline light duty vehicles, for which the emission control equipment is found working over a wide range of engine conditions. Our results confirm emission factors from the latest HBEFA model when deterioration and engine load are accounted for.



Europe's RDE

What is it?
An amendment to Euro 6 standards to make on-board (PEMS) testing part of type-approval. Triggered by high on-road diesel NOX results
Stakeholder working group is trying to define how the tests should be conducted (boundary conditions), how the data should be analyzed and reported
Pilot phase started in 2015, implementation in 2017
Driver of changes in Diesel NOX aftertreatment; implications on small Diesel PC market



Diesel vehicles in the EU are allowed a much higher NOx emission level than gasoline cars. In 2000, when the Euro 3 standard was introduced, the allowed level was 0.5 g/km, more than twice as much as for gasoline vehicles. Yet, as vehicle tests show, even back then the real on-road emission levels were closer to 1.0 g/km, i.e., much more than actually allowed by the standard. Still, the vehicles received their type-approval and could be sold, as the Euro emission standards have to be met under laboratory conditions only. Over time, emission limits got stricter, and the current Euro 5 emission standard sets a limit of 0.18 g/km for NOx diesel emissions. This is still more than three times as high as for gasoline vehicles, but of course much lower than back in 2000. However, recent research suggests that the on-road emissions did not really change at all during the last decade. The values measured are in the range of 0.8 g/km, only 20% lower than in 2000 and more than four times higher than allowed by the Euro 5 emission limit.

In the meantime, we Europeans may look jealously at California: there, emission limits for gasoline and diesel cars are identical, and about 75% lower than what is currently allowed for Euro 5 diesel cars in Europe. Furthermore, California also requires testing under additional driving cycles, and has greater durability requirements and in-use enforcement than Europe, resulting in better real-world emission performance. How much better exactly will be in the focus of an upcoming research project comparing on-road emissions of diesel cars in the EU and California.